US011709128B2

(12) United States Patent
Ho et al.

(10) Patent No.: US 11,709,128 B2
(45) Date of Patent: Jul. 25, 2023

(54) **OPTICAL DETECTION APPARATUS**

(71) Applicant: **Lextar Electronics Corporation**, Hsinchu (TW)

(72) Inventors: **Fu-Han Ho**, Hsinchu (TW); **Kai-Hung Cheng**, Hsinchu (TW)

(73) Assignee: **Lextar Electronics Corporation**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 132 days.

(21) Appl. No.: **17/244,912**

(22) Filed: **Apr. 29, 2021**

(65) **Prior Publication Data**

US 2022/0268690 A1 Aug. 25, 2022

(30) **Foreign Application Priority Data**

Feb. 22, 2021 (CN) 202110199183.4

(51) **Int. Cl.**
G01N 21/17 (2006.01)

(52) **U.S. Cl.**
CPC ***G01N 21/17*** (2013.01); *G01N 2201/062* (2013.01); *G01N 2201/08* (2013.01)

(58) **Field of Classification Search**
CPC G01N 21/17; G01N 2201/062; G01N 2201/08; A61B 5/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,558,161	B2 *	10/2013	Ong	G02B 19/008 250/221
9,752,925	B2	9/2017	Chu et al.	
10,128,401	B2 *	11/2018	Chen	H04N 1/00734
10,281,611	B2 *	5/2019	Uedaira	G01V 8/12
10,551,499	B2	2/2020	Hsu et al.	
10,610,159	B2	4/2020	Eletr et al.	
2015/0234941	A1	8/2015	Xiong et al.	
2019/0377858	A1	12/2019	He et al.	
2020/0096691	A1	3/2020	Nagamoto et al.	

FOREIGN PATENT DOCUMENTS

TW I547850 B 9/2016

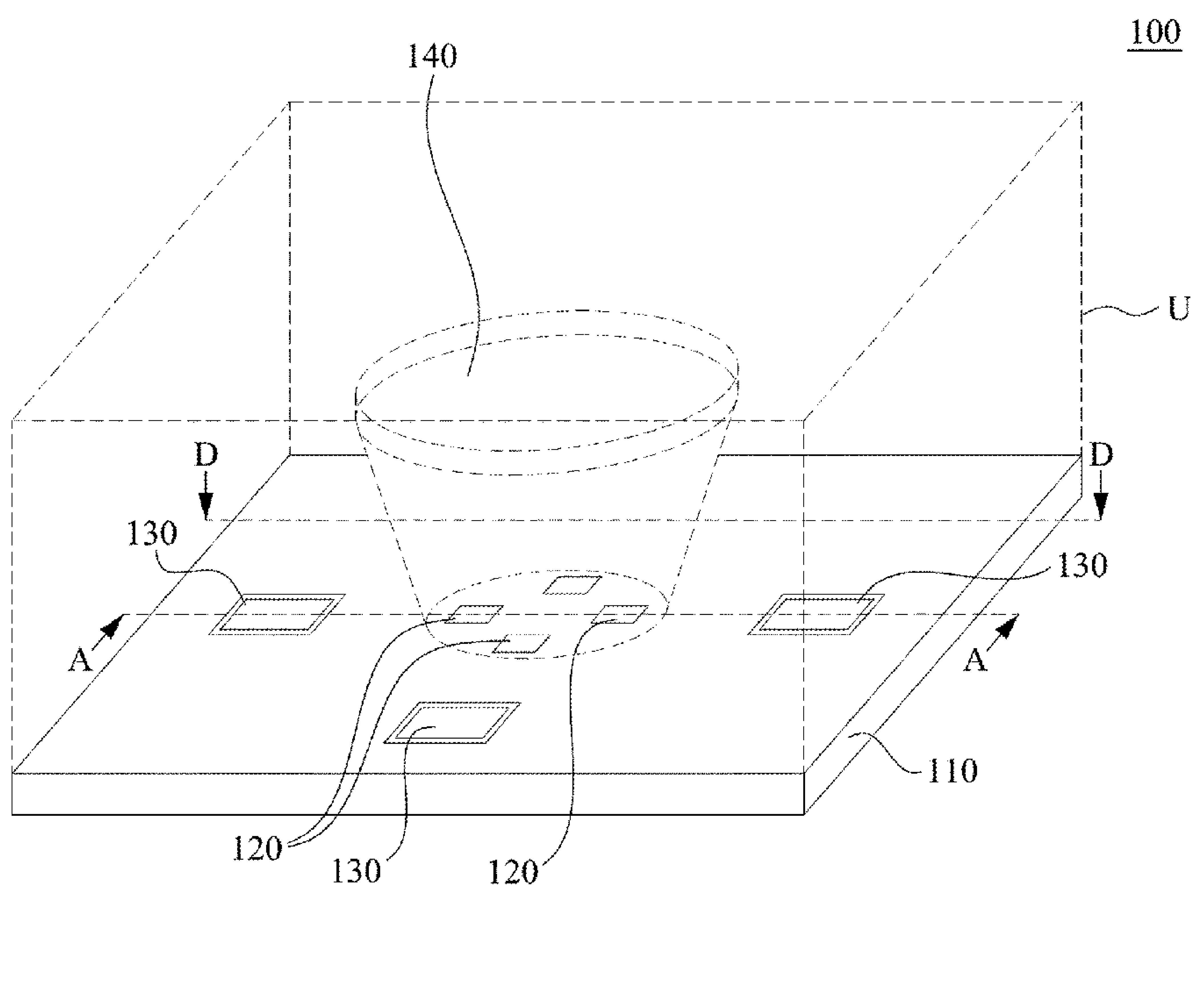
* cited by examiner

Primary Examiner — Seung C Sohn
(74) *Attorney, Agent, or Firm* — CKC & Partners Co., LLC

(57) **ABSTRACT**

An optical detection apparatus includes a substrate, a light source, a light sensor, a light-guiding structure. The substrate has a top surface. The light source on the top surface is configured to generate detection light toward an object over the light source. The light sensor is located on the top surface. The light-guiding structure is above the top surface and at least partially above the light source. A central axis of the light-guiding structure is vertical to the top surface, and the light source and the light sensor are at opposite sides relative to the central axis. The light-guiding structure is configured to deflect the detection light from one of the opposite sides at which the light source is located to another one of the opposite side at which the light sensor is located, such that the detection light reflected by the object moves toward the light sensor.

15 Claims, 10 Drawing Sheets



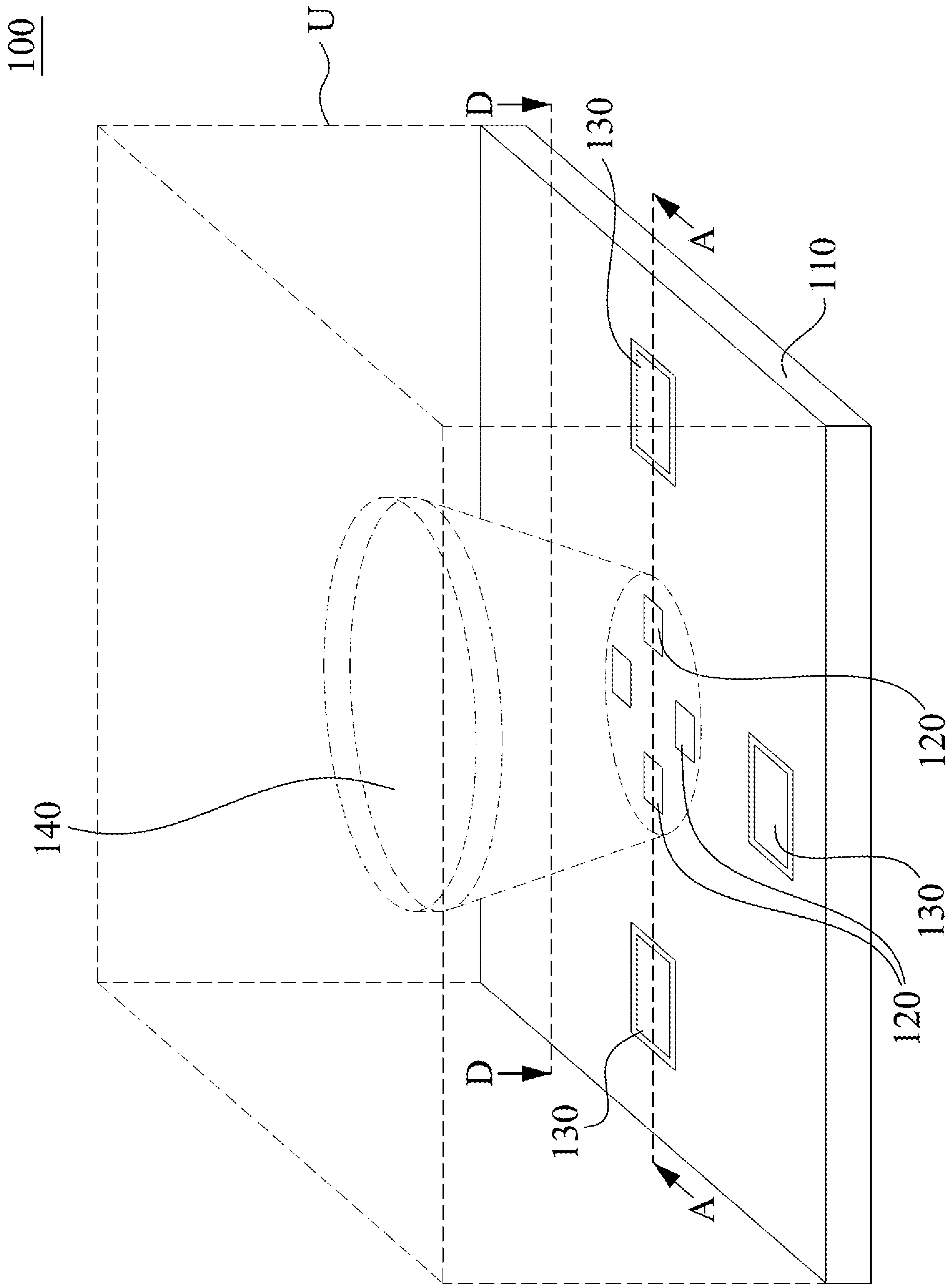


Fig. 1

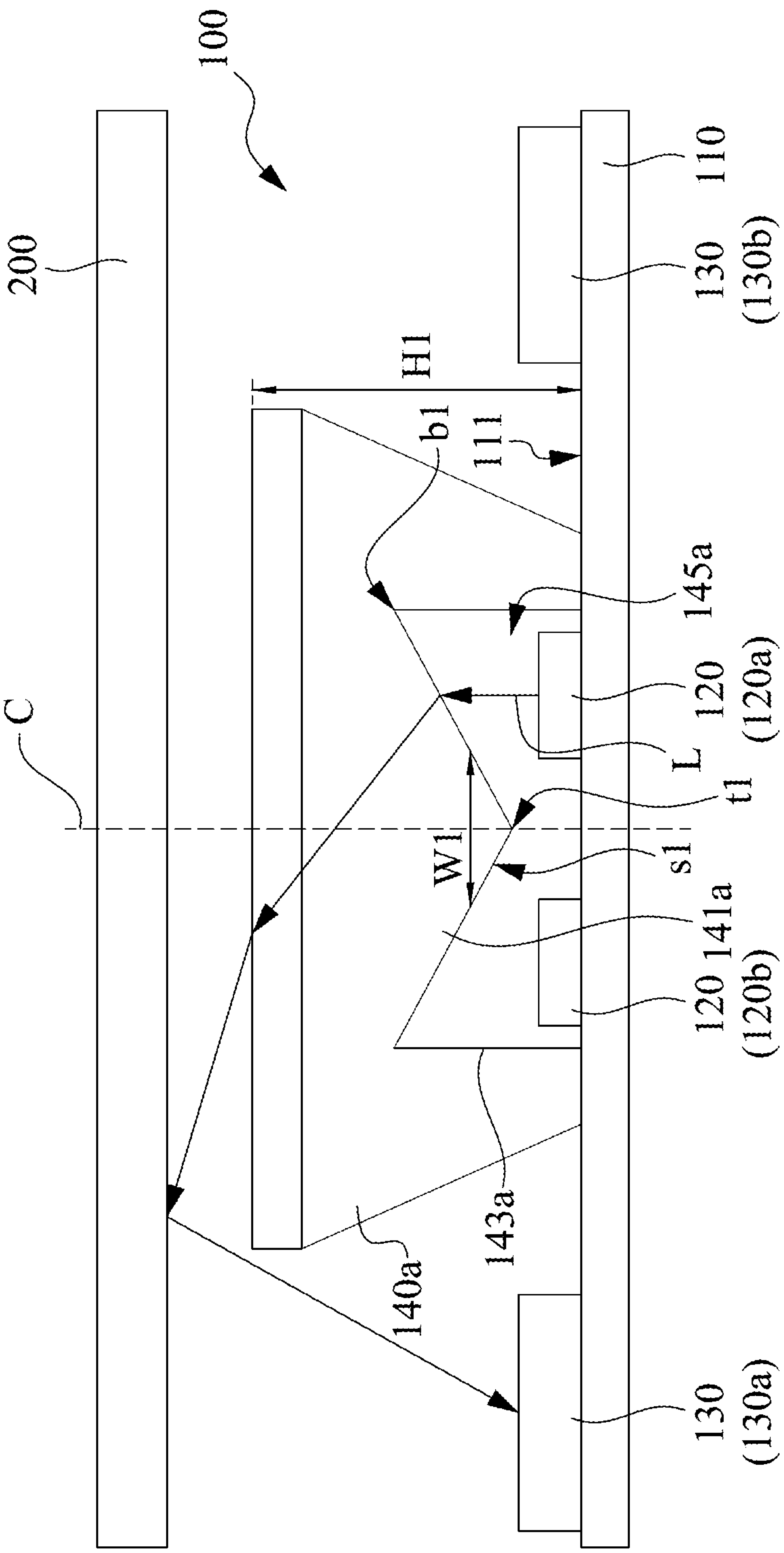

100
200
110
130
(130b)
H1
b1
111
145a
120
(120a)
L
t1
C
s1
W1
141a
120
(120b)
143a
140a
130
(130a)

Fig. 2

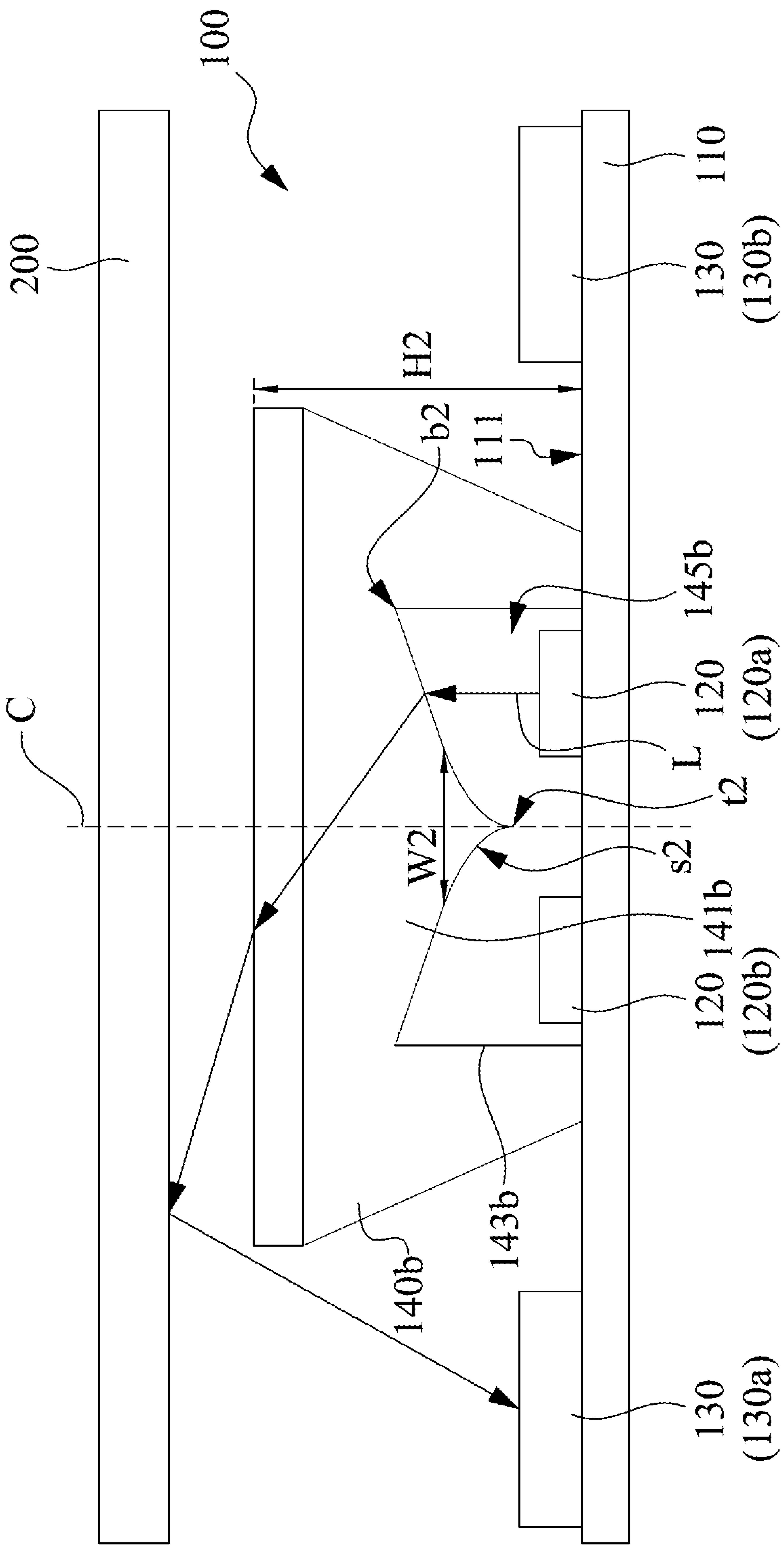

100
200
110
130
(130b)
H2
b2
111
145b
120
(120a)
L
C
t2
s2
W2
141b
120
(120b)
143b
140b
130
(130a)

Fig. 3

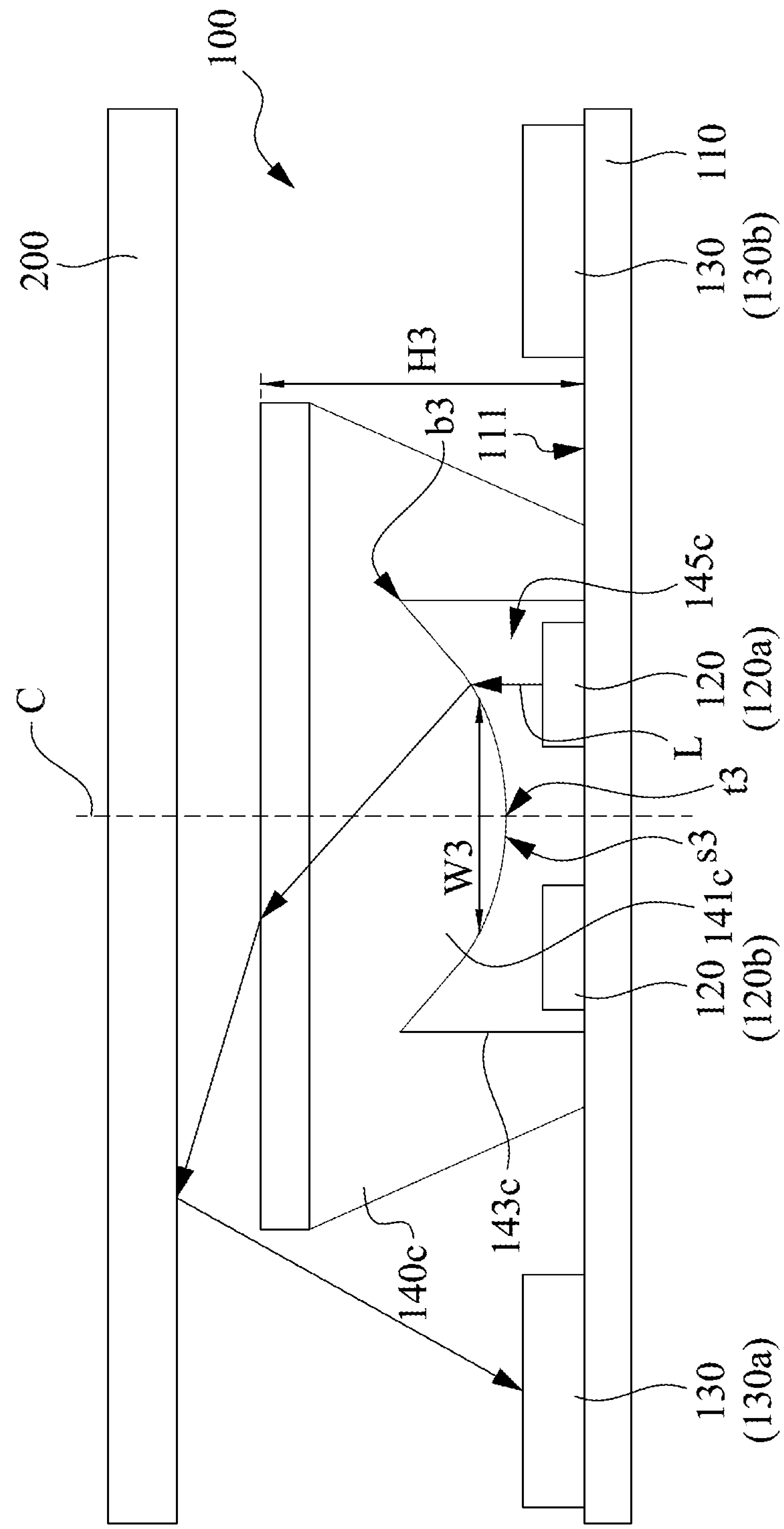

100
200
110
130
(130b)
H3
b3
111
145c
120
(120a)
L
C
t3
s3
W3
141c
120
(120b)
143c
140c
130
(130a)

Fig. 4

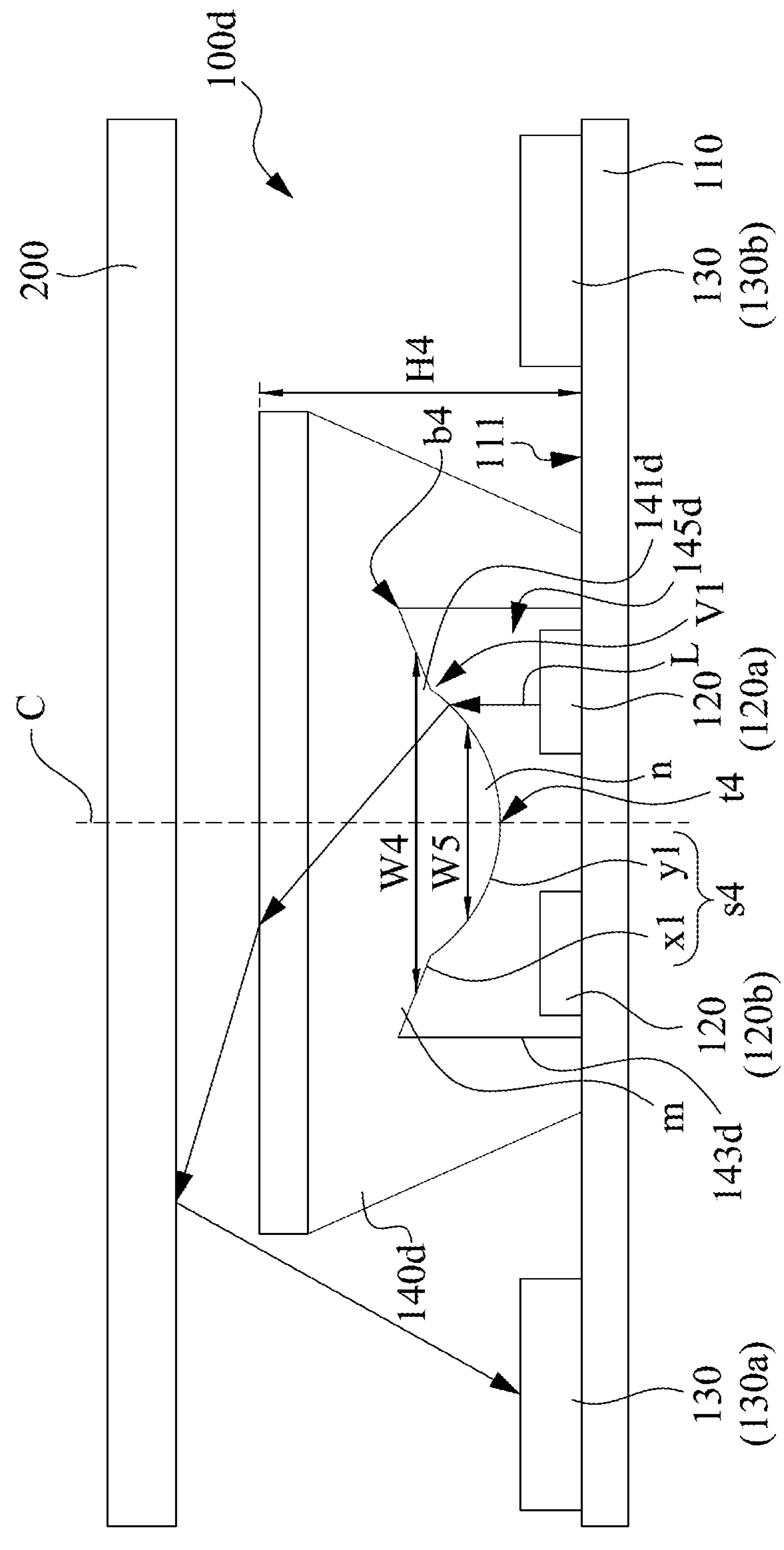

100d
200
110
130
(130b)
H4
111
b4
141d
145d
V1
L
120
(120a)
C
n
t4
W4
W5
y1
x1
s4
120
(120b)
m
143d
140d
130
(130a)

Fig. 5

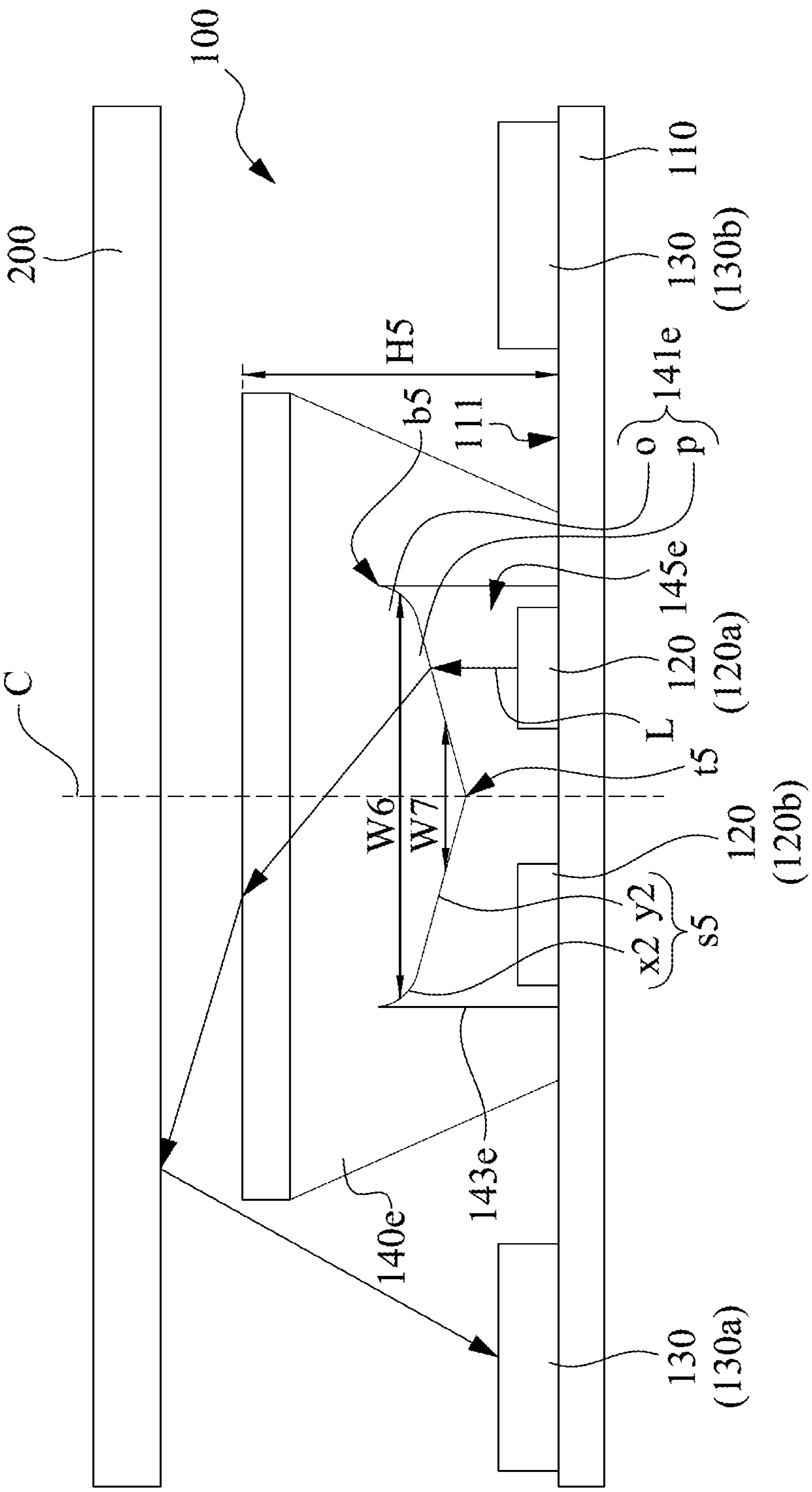

100
200
110
130
(130b)
H5
141e
b5
111
o
p
145e
C
120
(120a)
L
t5
W6
W7
120
(120b)
x2
y2
s5
143e
140e
130
(130a)

Fig. 6

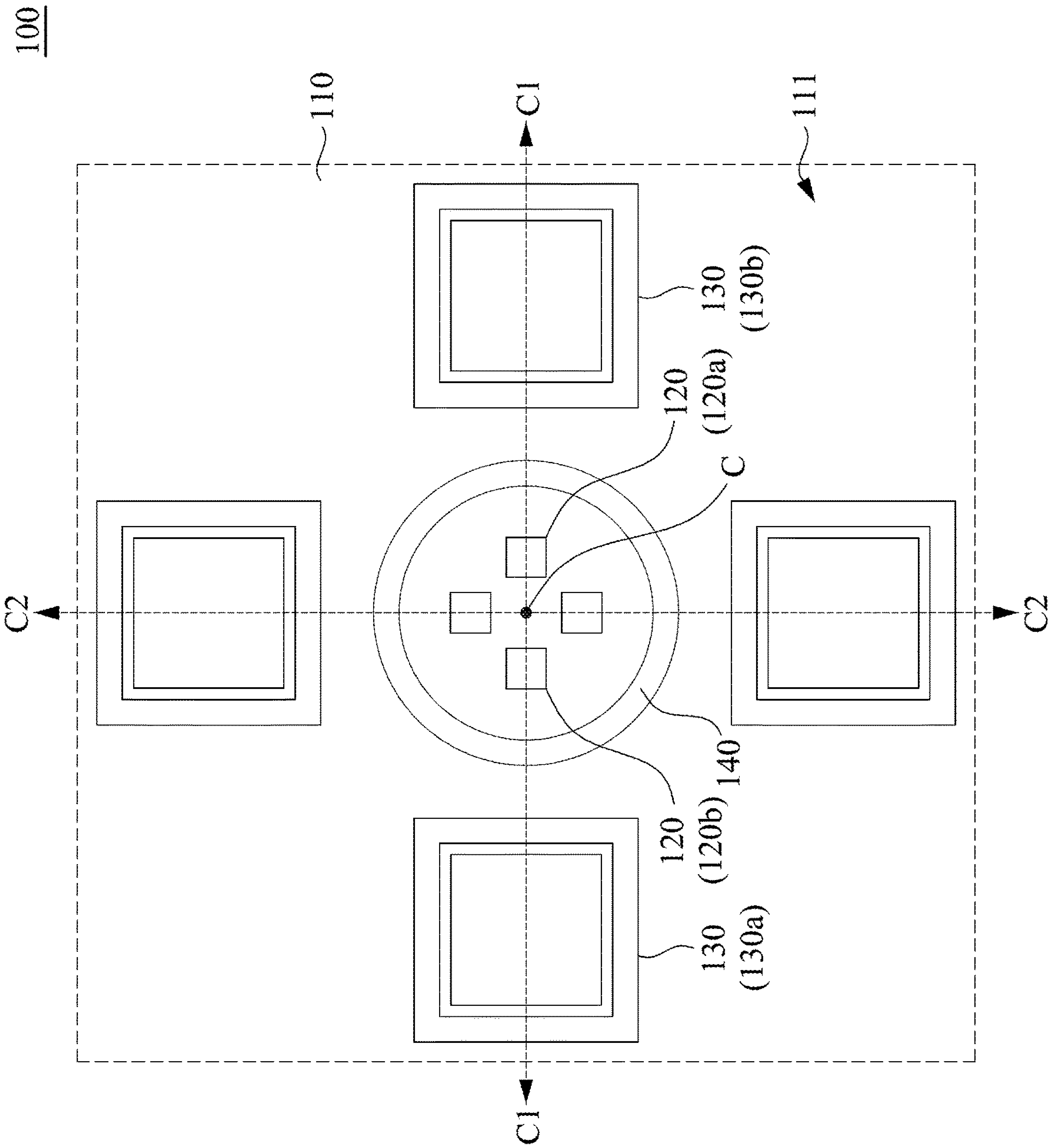


Fig. 7

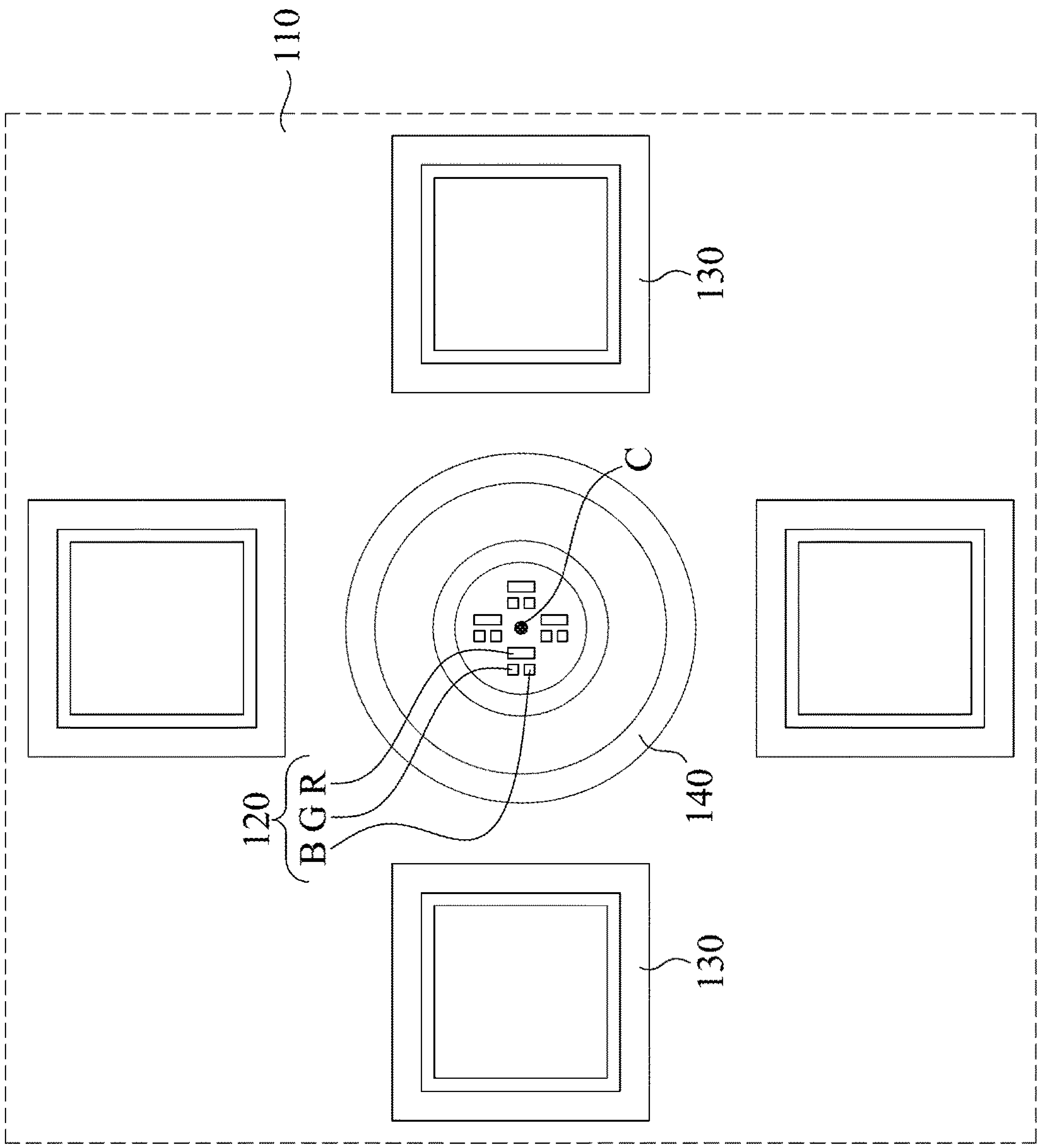


Fig. 8

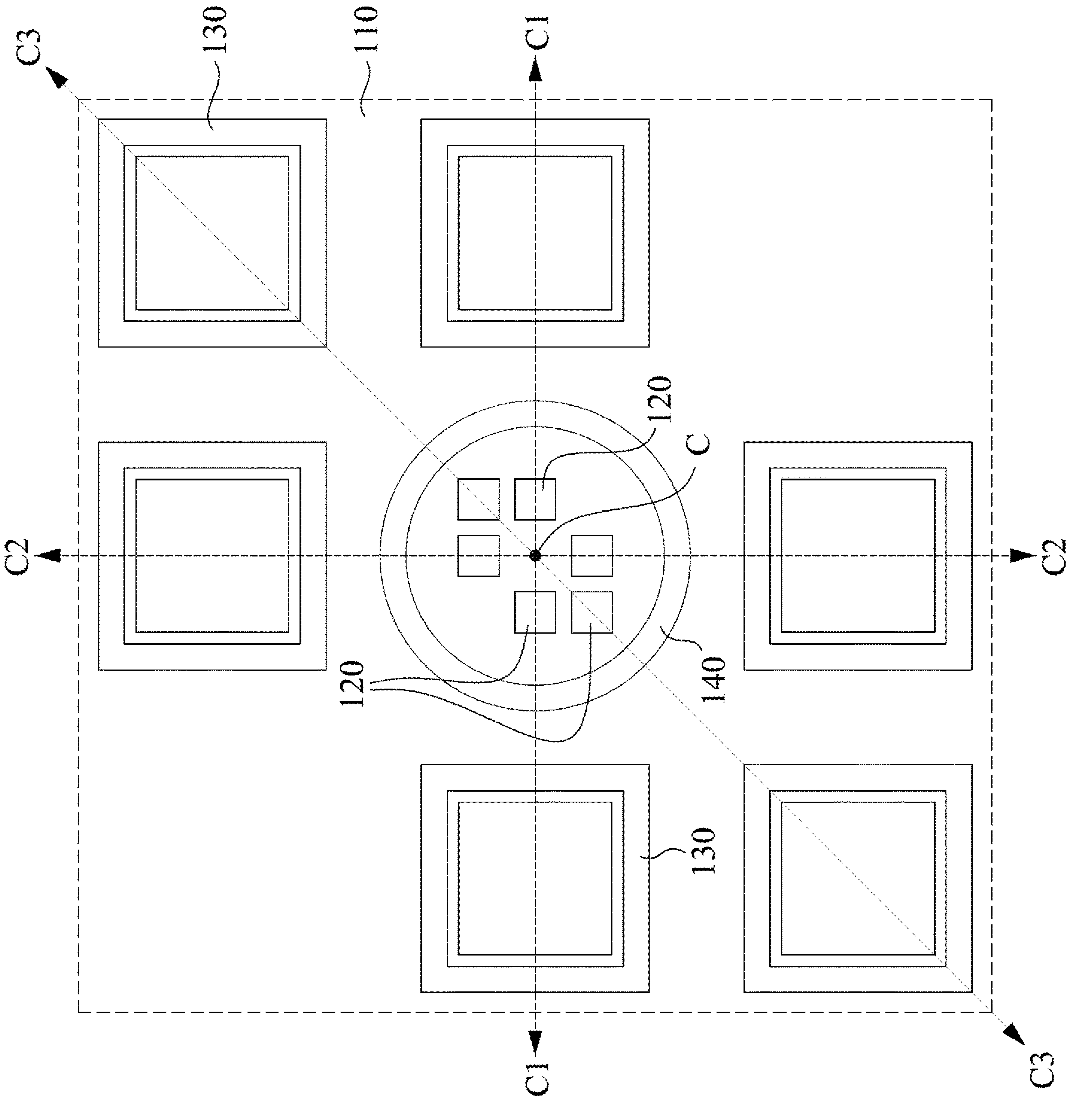


Fig. 9

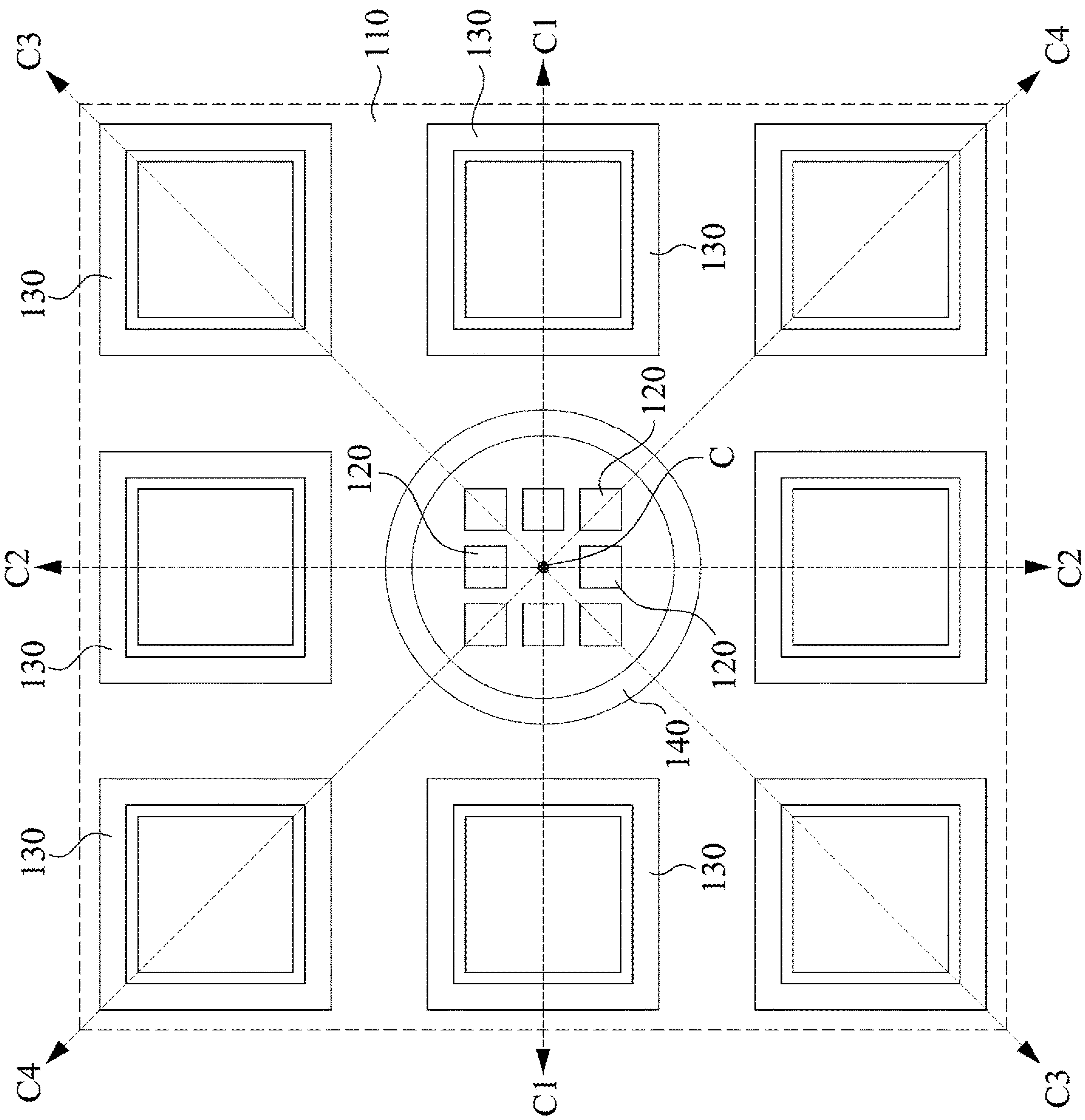

C3
110
130
C1
C4
130
130
120
120
C
C2
C2
130
120
140
130
130
C4
C1
C3

Fig. 10

OPTICAL DETECTION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to China Application Serial Number 202110199183.4, filed Feb. 22, 2021, which is herein incorporated by reference in its entirety.

BACKGROUND

Field of Invention

The present invention relates to an optical detection apparatus.

Description of Related Art

The medical testing technology has already progressed from invasive testing to non-invasive testing due to the advancement of science and technology.

In the process of detection, optical principles are used to detect a human body by some detection devices, and consumers always take the convenience of the optical detection devices in account. If the optical detection device is too large, it is unfavorable for the user to carry or wear. In addition, the manufacturers would like to show users new experience which is different from the existing optical detection devices, so as to attract more customers.

Therefore, how manufacturers can provide an optical detection device that can be miniaturized and innovative concepts for enhancing the convenience of use and product competitiveness has become one of the important issues.

SUMMARY

The invention provides an optical detection apparatus which includes a substrate, a light source, a light sensor, and a light-guiding structure. The substrate has a top surface. The light source on the top surface is configured to generate detection light toward an object over the light source. The light sensor is located on the top surface. The light-guiding structure is above the top surface and at least partially above the light source. A central axis of the light-guiding structure is vertical to the top surface, and the light source and the light sensor are at two opposite sides of the central axis. The light-guiding structure is configured to deflect the detection light from one of the two opposite sides at which the light source is located to the other one of the two opposite sides at which the light sensor is located, such that the detection light reflected by the object moves toward the light sensor.

In some embodiments of the present disclosure, the light-guiding structure includes a light-guiding convex portion which has a light incident surface. The light incident surface is inclined with respect to the central axis and configured for receiving the detection light.

In some embodiments of the present disclosure, the light-guiding structure comprises a cone-shaped light-guiding convex portion.

In some embodiments of the present disclosure, the light-guiding structure comprises a circular-arc shaped light-guiding convex portion.

In some embodiments of the present disclosure, the light-guiding structure comprises a column portion and a curved convex portion under the column portion.

In some embodiments of the present disclosure, the light-guiding structure comprises a column portion and a cone portion under the column portion.

In some embodiments of the present disclosure, the light-guiding structure includes a light-guiding convex portion and a lower recess portion which accommodates the light-guiding convex portion and the light source. The light-guiding structure is obliquely above the light source, and the light-guiding convex portion has a light incident surface. The light incident surface is inclined with respect to the central axis and configured for receiving the detection light.

In some embodiments of the present disclosure, the light-guiding structure is cup-shaped and accommodates the light source, and the light sensor is located outside the light-guiding structure.

In some embodiments of the present disclosure, the light-guiding structure has an M-shaped cross section.

In some embodiments of the present disclosure, the optical detection apparatus includes a plurality of the light sources and a plurality of the light sensors, in which each light source and each light sensor are located at the two opposite sides of the central axis.

In some embodiments of the present disclosure, the optical detection apparatus includes a plurality of the light sources and a plurality of the light sensors, and the light sources are among the light sensors.

In some embodiments of the present disclosure, the optical detection apparatus comprises a plurality of the light sources and a plurality of the light sensors, in which the light sources are centrosymmetric with respect to the central axis, and the light sensors are centrosymmetric with respect to the central axis.

In some embodiments of the present disclosure, the light-guiding structure has a height smaller than or equal to 100 um.

In some embodiments of the present disclosure, the light resource comprises a blue source, a green light source, or a red light source.

In some embodiments of the present disclosure, the light source comprises a mini light emitting diode or a micro light emitting diode.

In embodiments of the present disclosure, an optical detection apparatus is provided, and the optical detection apparatus a unique light-guiding structure. The light-guiding structure is configured to deflect the detection light from a side relative to a central axis of the light-guiding structure to another side thereof. In respect with light-guiding structure, a light source and a light sensor are respectively disposed at two different sides relative to the central axis. Therefore, the detection accuracy of the optical detection apparatus is improved, so as to adjust the passing path of the detection light and decrease the volume of the optical detection apparatus.

It is to be understood that both the foregoing general description and the following detailed description are by examples, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be more fully understood by reading the following detailed description of the embodiment, with reference made to the accompanying drawings as follows:

FIG. **1** illustrates a schematic view of an optical detection apparatus in accordance with some embodiments of the present disclosure;

FIGS. **2-6** respectively illustrate cross section views of the optical detection apparatus **100** of FIG. **1** in accordance with some embodiments of the present disclosure; and

FIGS. **7-10** respectively illustrate top views of the optical detection apparatus of FIG. **1** in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to the present embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

Reference is made to FIG. **1**. FIG. **1** illustrates a schematic view of an optical detection apparatus **100** in accordance with some embodiments of the present disclosure. The optical detection apparatus **100** includes a substrate **110**, a light source **120**, a light sensor **130**, and a light-guiding structure **140**. In some embodiments of the present disclosure, the light source **120** is configured to generate detection light, and the detection light is deflected by the light-guiding structure **140** to be projected on an object **200** such as human skin under test, such that the detection light which is further reflected by the object **200** can be received by the light sensor **130**. Moreover, the optical detection apparatus **100** further includes a housing U, in which the housing U accommodates and protects the light source **120**, the light sensor **130**, and the light-guiding structure **140**. In addition, the housing U can be made from a transparent material. The present disclosure is not limited in this respect.

Specifically, the substrate **110** can be a transparent substrate or a translucent substrate. For instance, the substrate **110** is a rigid substrate, a flexible substrate, a glass substrate, a sapphire substrate, a silicon substrate, a printed circuit board, a metal substrate, or a ceramic substrate. The present disclosure is not limited in this respect. Moreover, the light source **120** can include a blue light source, a green light source, a red light source, or an infrared light source, and the light source **120** can include a light-emitting diode (LED), such as an organic light-emitting diode (OLED), a mini light-emitting diode (mini LED), a micro light-emitting diode (micro LED), and so on. The present disclosure is not limited in this respect. In some embodiments of the present disclosure, the light sensor **130** is corresponding to a light frequency which is generated from the light source **120**. When the light source **120** includes a red light source and/or an infrared light source, the light sensor **130** has a red light sensor and/or an infrared light sensor, so as to detect blood oxygen saturation level. Moreover, when the light source **120** is a green light source, the light sensor **130** has a corresponding green light sensor, so as to detect human pulses. Specifically, the light sensor **130** can include a photodiode junction detector, a photomultiplier (PMT), a charge coupled device (CCD), or a complementary metal-oxide semiconductor (CMOS) sensor. The present disclosure is not limited in this respect. Specifically, the light-guiding structure **140** can include a transparent glass or a transparent polymer. The present disclosure is not limited in this respect.

Reference is made to FIG. **2**. FIG. **2** illustrates a cross section view of the optical detection apparatus **100** taken from a section line A in FIG. **1** in accordance with some embodiments of the present disclosure. In some embodiments of the present disclosure, the optical detection apparatus **100** includes a substrate **110**, a light source **120**, a light sensor **130**, and a light-guiding structure **140***a*, and the substrate **110** has a top surface **111**. The light source **120** is located on the top surface **111**, and the light source **120** is configured to generate detection light L moving toward an object **200** such as human skin above the light source **120**. The light sensor **130** is located on the top surface **111**. The light-guiding structure **140***a* is above the top surface **111** and at least partially above the light source **120**. A central axis C which passes through a center of the light-guiding structure **140***a* is vertical to the top surface **111**, and the light-guiding structure **140***a* is symmetric with respect to the central axis by reflection symmetry or central symmetry. The light source **120** and the light sensor **130** are located at two opposite sides relative to the central axis C, and the light-guiding structure **140***a* is configured to deflect the detection light L which comes from one of the two opposite sides at which the light source **120** is located to move toward another one of the two opposite sides at which the light sensor **130** is located. Therefore, the object **200** reflects the detection light L, so as to project the detection light L on the light sensor **130**. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the optical detection apparatus **100** includes a first light source **120***a*, a second light source **120***b*, a first light sensor **130***a*, and a second light sensor **130***b*. The first light source **120***a* and the first light sensor **130***a* are located at two opposite sides relative to the central axis C, thus the central axis C is located between the first light source **120***a* and the first light sensor **130***a*. The detection light L generated by the first light source **120***a* is deflected to a surface of the object **200**, and then the object **200** reflects the detection light L to move toward the first light sensor **130***a*. Therefore, the first light sensor **130***a* and the second light sensor **130***b* can efficiently receive light, so as to improve the detection accuracy of the optical detection apparatus **100**. In order to miniaturize the optical detection apparatus **100**, it is benefit to deflect the passing path of the detection light L.

Similarly, the second light source **120***b* and the second light sensor **130***b* are located at two opposite sides relative to the central axis C, thus the central axis C is located between the second light source **120***b* and the second light sensor **130***b*. The detection light L generated by the second light source **120***b* would be deflected by the light-guiding structure **140***a*, and then the object **200** reflects the detection light L to move toward the second light sensor **130***b*. Therefore, the second light sensor **130***b* can efficiently receive light.

In some embodiments of the present disclosure, a straight line such as the cross section line A in FIG. **1** can passes through the first light source **120***a*, the second light source **120***b*, the first light sensor **130***a* and the second light sensor **130***b*. Therefore, the first light source **120***a*, the second light source **120***b*, the first light sensor **130***a*, and the second light sensor **130***b* occupy very small space of the optical detection apparatus **100**, so as to miniaturize the optical detection apparatus **100**. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***a* includes a light-guiding convex portion **141***a* which has a light incident surface s**1** inclined with respect to the central axis C. The light-guiding convex portion **141***a* is defined between a bottom end portion t**1** and a top edge portion b**1** thereof, and a straight line which extends from the bottom end portion t**1** to the top edge portion b**1** is inclined with respect to central axis C. The light incident surface s**1** is configured for receiving the detection light L, and the detection light L enters the light-guiding convex portion **141***a* from the light incident surface s**1**, such that the light-guiding structure **140***a* further deflects the detection light L. Specifically, the light-guiding convex portion **141***a* is cone-shaped. For instance, the light-guiding convex portion **141***a* is a circular cone, a triangular cone, quadrangular cone, or any suitable polygonal cone. The light-guiding convex portion **141***a* has a width W**1** which gradually decreases toward the substrate **110**, and the light incident surface s**1** can be flat or curved. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***a* has the light-guiding convex portion **141***a*, a sidewall **143***a*, and a lower recess portion **145***a*, in which the sidewall **143***a* surrounds the light-guiding convex portion **141***a* and the light source **120**, so as to form the lower recess portion **145***a*. In other words, the light-guiding convex portion **141***a* and the sidewall **143***a* collectively form and define the lower recess portion **145***a*. Moreover, the lower recess portion **145** accommodates the light source **120** and the light-guiding convex portion **141***a*, and the light-guiding convex portion **141***a* is obliquely above the light source **120**, such that the light incident surface s**1** of the light-guiding convex portion **141***a* can efficiently receive the detection light L. The present disclosure is not limited in this respect. In FIG. **2**, the light-guiding convex portion **141***a* and the sidewall **143***a* collectively form an M-shaped cross section, and the light-guiding structure **140***a* has an M-shaped outline. In some embodiments of the present disclosure, the light-guiding structure **140***a* is cup-shaped. The light-guiding structure **140***a* accommodates the light source **120**, but the light sensor **130** is outside the light-guiding structure **140***a*. In addition, the light-guiding structure **140***a* has a height H**1** which is equal to or smaller than 100 um. Therefore, the volume of the optical detection apparatus **100** can be decreased, so as to adjust the passing path of the detection light L. In some embodiments, the light-guiding structure **140***a* has a height H**1** which is equal to or smaller than 75 um. The present disclosure is not limited in this respect.

Reference is made to FIG. **3**. FIG. **3** illustrates a cross section view of the optical detection apparatus **100** taken from the cross section line A in FIG. **1** in accordance with some embodiments of the present disclosure. FIGS. **2** & **3** are substantially the same, and the light-guiding structure **140***a* in FIG. **2** is different from a light-guiding structure **140***b* in FIG. **3**. Therefore, the similar details are not repeated in the present disclosure. In some embodiments of the present disclosure, the light-guiding structure **140***b* has a light-guiding convex portion **141***b*, and the light-guiding convex portion **141***b* has a light incident surface s**2** which is inclined with respect to central axis C. The light-guiding convex portion **141***b* is defined between a bottom end portion t**2** and a top edge portion b**2** thereof, and a straight line passing through the bottom end portion t**2** and the top edge portion b**2** is inclined with respect to the central axis C. The light incident surface s**2** is configured for receiving the detection light L, and the detection light L enters the light-guiding convex portion **141***b* from the light incident surface s**2** enters, such that the light-guiding structure **140***b* can deflect the detection light L. Specifically, the light-guiding convex portion **141***b* is cone-shaped, and the light-guiding convex portion **141***b* has a width W**2** which gradually decrease toward substrate **110**. Moreover, the light incident surface s**2** is a curved concave surface. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***b* has the light-guiding convex portion **141***b*, a sidewall **143***b*, and a lower recess portion **145***b*, and the sidewall **143***b* surrounds the light-guiding convex portion **141***b* and the light source **120**, so as to form the lower recess portion **145***b*. In other words, the light-guiding convex portion **141***b* and the sidewall **143***b* collectively form and define the lower recess portion **145***b*. In FIG. **3**, the light-guiding convex portion **141***b* and the sidewall **143***b* collectively form an M-shaped cross section, thus the light-guiding structure **140***b* has an M-shaped outline. In some embodiments of the present disclosure, the light-guiding structure **140***b* is cup-shaped. The light-guiding structure **140***b* accommodates the light source **120**, but the light sensor **130** is located outside the light-guiding structure **140***b*. In addition, the light-guiding structure **140***b* has a height H**2** which is equal to or smaller than 100 um. Therefore, the volume of the optical detection apparatus **100** can be decreased, so as to adjust the passing path of the detection light L. In some embodiments of the present disclosure, the light-guiding structure **140***b* has a height H**2** equal to or smaller than 75 um. The present disclosure is not limited in this respect.

Reference is made to FIG. **4**. FIG. **4** illustrates a cross section view of the optical detection apparatus **100** taken from the cross section line A in FIG. **1** according to some embodiments of the present disclosure. FIG. **4** and FIG. **2** are substantially the same, but a light-guiding structure **140***c* of the optical detection apparatus **100** in FIG. **4** is different from the light-guiding structure **140***a* in FIG. **2**. Therefore, the similar details are not repeated in the present disclosure. In some embodiments of the present disclosure, the light-guiding structure **140***c* has a light-guiding convex portion **141***c* which is circular-arc shaped, and the light-guiding convex portion **141***c* is inclined with respect to a light incident surface s**3** of the central axis C. The light-guiding convex portion **141***c* is defined between a bottom end portion t**3** and a top edge portion b**3** thereof, and a straight line which passes through the bottom end portion t**3** and the top edge portion b**3** is inclined with respect to the central axis C. The light incident surface s**3** is configured to receive the detection light L, and the detection light L enters the light-guiding convex portion **141***c* from the light incident surface s**3**, such that the light-guiding structure **140***c* can deflect the detection light L. Specifically, the light-guiding convex portion **141***c* is circular-arc-shaped, and the light-guiding convex portion **141** has a width W**3** which gradually decreases toward the substrate **110**, and the light incident surface s**3** is a curved convex surface. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***c* has the light-guiding convex portion **141***c*, a sidewall **143***c*, and a lower recess portion **145***c*, and the sidewall **143***c* surrounds the light-guiding convex portion **141***c* and the light source **120** to form the lower recess portion **145***c*. In other words, the light-guiding convex portion **141***c* and the sidewall **143***c* collectively form and define the lower recess portion **145***c*. In FIG. **4**, the light-guiding convex portion **141** and the sidewall **143***c* collectively form an M-shaped cross section, and the light-guiding structure **140***c* has an M-shaped outline. In some embodiments of the present disclosure, the light-guiding structure **140***c* is cup-shaped, and the light-guiding structure **140***c* accommodates the light source **120**. On the other hand, the light sensor **130** is located outside the light-guiding structure **140***c*, and the light-guiding structure **140***c* has a width H**3** which is equal to or smaller than 100 um. The volume of the optical detection apparatus **100** can be decreased, so as to adjust the passing path of the detection light L. In some embodiments, the light-guiding structure **140***c* has a height H**3** equal to or smaller than 75 um. The present disclosure is not limited in this respect.

Reference is made to FIG. **5**. FIG. **5** illustrates a cross section view of the optical detection apparatus **100** taken from the cross section line A in FIG. **1**. FIG. **2** and FIG. **5** are substantial the same, but a light-guiding structure **140***d* of the optical detection apparatus **100** in FIG. **5** is different from the light-guiding structure **140***a* in FIG. **2**. Therefore, the similar details are not repeated in the present disclosure. In some embodiments of the present disclosure, the light-guiding structure **140***d* has the a light-guiding convex portion **141***d*, the light-guiding convex portion **141***d* has a light incident surface s**4** which is inclined with respect to the central axis C. The light-guiding convex portion **141***d* is defined between a bottom end portion t**4** and a top edge portion b**4**, and a straight line pasting through the bottom end portion t**4** and the top edge portion b**4** is inclined with respect to the central axis C. The light incident surface s**4** is configured for receiving the detection light L, and the detection light L enters the light-guiding convex portion **141***d* from the light incident surface s**4**, such that the light-guiding structure **140***d* deflects the detection light L. Specifically, the light-guiding convex portion **141***d* has a column portion m and a curved convex portion n under the column portion m, and the column portion m can be a triangular column, a quadrangular column, a pentagonal column, a hexagonal column, an octagonal column, or a cylinder. The column portion m is connected to and located on the curved convex portion n. The column portion m has a flat surface x**1**, and the curved convex portion n has a curved surface y**1**. The flat surface x**1** and the curved surface y**1** collectively form the light incident surface s**4**. Moreover, there is a curvature inversion point V**1** on the light incident surface s**4**, and the curvature inversion point V**1** is at the position where column portion m joins the curved convex portion n. More specifically, the curvature inversion point V**1** is at a position where the flat surface x**1** joins the curved surface y**1**. Moreover, a width W**4** of the column portion m gradually decreases toward the substrate **110**, and a width W**5** of the curved convex portion n gradually decreases toward the substrate **110**. The width W**4** of the column portion m is equal to or greater than the width W**5** of the curved convex portion n. The present is not disclosed in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***d* has the light-guiding convex portion **141***d*, a sidewall **143***d*, and the lower recess portion **145***d*, in which the sidewall **143***d* surrounds the light-guiding convex portion **141***d* and the light source **120** to form the lower recess portion **145***d*. Therefore, the light-guiding convex portion **141***d* and the sidewall **143***d* collectively form and define the lower recess portion **145***d*. In FIG. **5**, the light-guiding convex portion **141***d* and the sidewall **143***d* collectively form an M-shaped cross section, and the light-guiding structure **140***d* has an M-shaped outline. In some embodiments of the present disclosure, the light-guiding structure **140***d* is cup-shaped, the light-guiding structure **140***d* accommodates the light source **120**, and the light sensor **130** is located outside the light-guiding structure **140***d*. Moreover, the light-guiding structure **140***d* has a width H**4** which is equal to or smaller than 100 um. The volume of the optical detection apparatus **100** can be decreased, so as to adjust the passing path of the detection light L. In some embodiments, the light-guiding structure **140***d* has a height H**4** equal to or smaller than 75 um.

Reference is made to FIG. **6**. FIG. **6** illustrates a cross section view of the optical detection apparatus **100** taken from the cross section line A in FIG. **6**. FIG. **2** and FIG. **6** are substantially the same, but a light-guiding structure **140***e* of the optical detection apparatus **100** in FIG. **6** is different from the light-guiding structure **140***a* in FIG. **2**. Therefore, the similar details are not repeated in the present disclosure. In some embodiments of the present disclosure, the light-guiding structure **140***e* has the light-guiding convex portion **141***e*, and the light-guiding convex portion **141***e* has a light incident surface s**5** which inclined with respect to the central axis C. The light-guiding convex portion **141***e* is defined between a bottom end portion t**5** and a top edge portion b**5** thereof, and a straight line passing through the bottom end portion t**5** and the top edge portion b**5** is inclined with respect to the central axis C. The light incident surface s**5** is configured for receiving the detection light L, and the detection light L enters the light-guiding convex portion **141***e* from the light incident surface s**5**, such that the light-guiding structure **140***e* can deflect the detection light L.

Specifically, the light-guiding convex portion **141***e* has a column portion o and a cone portion p, and the column portion o can be a triangular column, quadrangular column, a pentagonal column, a hexagonal column, an octagonal column or a cylinder. The present disclosure is not limited in this respect. The cone portion p which is corresponding to the column portion o can be a triangular cone, a quadrangular pyramid, a pentagonal cone, a hexagonal cone, an octagonal cone, or a circular cone. The column portion o is connected to and located on the cone portion p. The column portion o has a curved convex surface x**2**, and the cone portion p has a flat surface y**2**. The curve convex surface x**2** and the flat surface y**2** collectively form a light incident surface s**5**. Moreover, the column portion o has a width W**6** which gradually decreases toward the substrate **110**, and the cone portion p has a width W**7** which gradually decreases toward the substrate **110**. The width W**6** of the column portion o is equal to or greater than a width W**7** of the cone portion p. The present disclosure is not limited in this respect.

In some embodiments of the present disclosure, the light-guiding structure **140***e* has the light-guiding convex portion **141***e*, a sidewall **143***e*, and a lower recess portion **145***e*. The sidewall **143***e* surrounds the light-guiding convex portion **141***e* and the light source **120** to form the lower recess portion **145***e*. In other words, the light-guiding convex portion **141***e* and the sidewall **143***e* collectively form and define the lower recess portion **145***e*. In FIG. **6**, the light-guiding convex portion **141***e* and the sidewall **143***e* collectively form an M-shaped cross section, and the light-guiding structure **140***e* has an M-shaped outline. In some embodiments of the present disclosure, the light-guiding structure **140***e* is cup-shaped, and the light source **120** is accommodated in the light-guiding structure **140***e*. On the other hand, the light sensor **130** is located outside the light-guiding structure **140***e*. Moreover, the light-guiding structure **140***e* has a height H**2** which is equal to or smaller than 100 um. Therefore, the volume of the optical detection apparatus **100** can be decreased, so as to adjust the passing path of the detection light L. In some embodiments, the light-guiding structure **140***d* has a height H**5** which is equal to or smaller than 75 um.

Reference is made to FIG. **7**. FIG. **7** illustrates a top view of the optical detection apparatus **100** in FIG. **1** taken from a vertical position D. In some embodiments of the present disclosure, the optical detection apparatus **100** includes a plurality of the light sources **120** such as four light sources

120 and a plurality of the light sensors **130** such as four light sensors **130**. The light sources **120** surround the central axis C, and the light sensors **130** surrounds the central axis C and the light sources **120**. Therefore, the light sources **120** are among the light sensors **130**, and the central axis C does not pass any light source **120**. Specifically, the light sensors **130** are respectively opposite to the light sources **120** with respect to the central axis C, and the light sources **120** and the light sensors **130** are centrosymmetric with respect to the central axis C. That is, the locations of the four light sources **120** are centrosymmetric with respect to the central axis C, and the locations of the four light sensors **130** are centrosymmetric with respect to the central axis C rather than referring to the shapes of the light sources **120** and the light sensors **130** are symmetrical.

FIG. **7** illustrate a first straight line C**1** and a second straight line C**2** which is vertical to the first straight line C**1**, in which the first straight line C**1** and the second straight line C**2** are vertical to the central axis C. In some embodiments of the present disclosure, four light sources **120** surround the central axis C, and four light sensors **130** surround the light sources **120** and the central axis C. The first straight line C**1** passes through two light sources **120** and two light sensors **130**, and the second straight line C**2** passes another two light sources **120** and another two light sensors **130**. Therefore, the volume of the optical detection apparatus **100** can be decreased, and the interference among the four light sources **120** can be curbed, so as to improve the detection accuracy of the optical detection apparatus **100**. In other embodiments of the present disclosure, the first straight line C**1** crosses the second line C**2** and form an angle which is not 90 degree, thus light sources **120** and the light sensors **130** are not centrosymmetric with respect to the central axis C. The present disclosure is not limited in this respect.

Specifically, the first straight line C**1** passes through a first light source **120***a*, a second light source **120***b*, a first light sensor **130***a*, and a second light sensor **130***b*, in which the first light source **120***a* and the second light source **120***b* is between the first light sensor **130***a* and the second light sensor **130***b*. The first light source **120***a* and the second light source **120***b* are inside the light-guiding structure **140**, and the first light sensor **130***a* and the second light sensor **130***b* are outside the light-guiding structure **140**. Similarly, the second straight line C**2** passes through another two light source **120** and another two light sensors **130**, in which the another two first light sources **120** are between the another two light sensors **130**. The present disclosure is not limited in this respect.

Reference is made to FIGS. **7** and **8**, and the optical detection apparatus **100** shown in FIG. **7** is similar to the optical detection apparatus **100** shown in FIG. **8**. FIG. **8** further shows that the light source **120** which includes a blue light source B, a green light source G, and a red light source R. In some embodiments of the present disclosure, the light source **120** further includes an infrared light source, and the present disclosure is not limited in this respect. In FIG. **8**, a plurality of the light sources **120** surround the central axis C, and a plurality of the light sensors **130** surround the central axis C and the light sources **120**. Therefore, the light sources **120** are among the light sensors **130**, and the present disclosure is not limited in this respect. In some embodiments, the light sources **120** can generate light which has different frequency bands, such as blue light, green light, red light, and infrared light.

Reference is made to FIG. **9**. FIG. **9** is similar to FIG. **7**, and the optical detection apparatus **100** in FIG. **9** includes six light sources **120** and six light sensors **130**. The six light sources **120** surround the central axis C, and the six light sensors **130** surround the central axis C and the six light sources **120**. In other words, the central axis C does not pass through any light source **120**. Moreover, the six light sources **120** are in the light-guiding structure **140**, and the six light sensors **130** are located outside the light-guiding structure **140**. The present disclosure is not limited in this respect.

In comparison with FIG. **7**, FIG. **9** further illustrates a third straight line C**3**, and the third straight line C**3** is vertical to the central axis C and crosses the first straight line C**1** and the second straight line C**2**. The first straight line C**1** and the third straight line C**3** form an angle which is 45 degree, and the second straight line C**2** and the third straight line C**3** form an angle which is 45 degree. In some embodiments of the present disclosure, each one of the first straight line C**1**, the second straight line C**2**, and the third straight line C**3** passes two of the light sources **120** and two of the light sensors **130**. Specifically, the six light sources **120** and the six light sensors **130** are symmetrical with respect to the third straight line C**3**. That is, locations of the six light sources **120** and the six light sensors **130** are symmetrical with respect to the third straight line C**3** rather than referring to the shapes of the light sources **120** and the light sensors **130** are symmetrical. Therefore, the volume of the optical detection apparatus **100** can be decreased, and interference among the light sources **120** can be curbed, so as to improve the detection accuracy of the optical detection apparatus **100**. In other embodiments of the present disclosure, the third straight line C**3** can form an angle in any degree with the first straight line C**1** or the second straight line C**2**. Therefore, the light sources **120** and light sensors **130** are not symmetrical with respect to the central axis C. The present disclosure is not limited in this respect.

Reference is made to FIG. **10**. FIG. **10** is similar to FIG. **9**, and the optical detection apparatus **100** has eight light sources **120** and eight light sensors **130**. The eight light sources **120** surround the central axis C, and the light sensors **130** surround the central axis C and the eight light sources **120**. Therefore, the central axis C does not pass through any light source **120**. Moreover, the eight light sources **120** are in the light-guiding structure **140**, and the eight light sensors **130** are outside the light-guiding structure **140**. The present disclosure is not limited in this respect.

In comparison with FIG. **9**, FIG. **10** further illustrates a fourth straight line C**4**, and the fourth straight line C**4** is vertical to the central axis C and the third straight line C**3**. In some embodiments of the present disclosure, each one of the first straight line C**1**, the second straight line C**2**, the third straight line C**3**, and the fourth straight line C**4** passes through two of the light sources **120** and two of the light sensors **130**. Moreover, the eight light sources **120** and the eight light sensors **130** are centrosymmetric with respect to the central axis C, so as to decrease the volume of the optical detection apparatus **100** and curb the interference among the light sources **120**. Therefore, the detection accuracy of the optical detection apparatus **100** is improved. In some other embodiments of the present disclosure, the third straight line C**3** is not vertical to the fourth straight line C**4**, and the eight light sources **120** and the eight light sensors **130** are not centrosymmetric with respect to the central axis C. The present disclosure is not limited in this respect.

In embodiments of the present disclosure, an optical detection apparatus is provided, and the optical detection apparatus a unique light-guiding structure. The light-guiding structure is configured to deflect the detection light from a side of a central axis of the light-guiding structure to another side thereof. In respect with light-guiding structure, a light source and a light sensor are respectively disposed at two different sides of the central axis. Therefore, the detection accuracy of the optical detection apparatus is improved, so as to adjust the passing path of the detection light and decrease the volume of the optical detection apparatus.

Although the present invention has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims.

What is claimed is:

1. An optical detection apparatus comprising:

a substrate having a top surface;

a light source on the top surface is configured to generate detection light toward an object over the light source;

a plurality of light sensors on the top surface and surrounding the light source; and

a light-guiding structure above the top surface and at least partially above the light source, and a central axis of the light-guiding structure is vertical to the top surface, the light source and the light sensors are disposed at two opposite sides of the central axis, wherein the light-guiding structure is configured to deflect the detection light from one of the two opposite sides at which the light source is located to the other one of the two opposite sides at which one of the light sensors is located, such that the detection light reflected by the object moves toward the one of the light sensors.

2. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a light-guiding convex portion which has a light incident surface inclined with respect to the central axis and configured for receiving the detection light.

3. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a cone-shaped convex portion.

4. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a circular-arc-shaped convex portion.

5. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a column portion and a curved convex portion under the column portion.

6. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a column portion and a cone portion under the column portion.

7. The optical detection apparatus of claim **1**, wherein the light-guiding structure comprises a light-guiding convex portion and a lower recess portion which accommodates the light-guiding convex portion and the light source, the light-guiding convex portion is obliquely above the light source, and the light-guiding convex portion has a light incident surface inclined with respect to the central axis and configured for receiving the detection light.

8. The optical detection apparatus of claim **1**, wherein the light-guiding structure is cup-shaped and accommodates the light source, and the light sensors are disposed outside the light-guiding structure.

9. The optical detection apparatus of claim **1**, wherein the light-guiding structure has an M-shaped cross section.

10. The optical detection apparatus of claim **1** comprising a plurality of the light sources, wherein each light source and each light sensor are located at the two opposite sides of the central axis.

11. The optical detection apparatus of claim **1** comprising a plurality of the light sources, wherein the light sources are disposed among the light sensors.

12. The optical detection apparatus of claim **1** comprising a plurality of the light sources, wherein the light sources are centrosymmetric with respect to the central axis, and the light sensors are centrosymmetric with respect to the central axis.

13. The optical detection apparatus of claim **1**, wherein the light-guiding structure has a height smaller than or equal to 100 um.

14. The optical detection apparatus of claim **1**, wherein the light source comprises a blue source, a green light source, or a red light source.

15. The optical detection apparatus of claim **1**, wherein the light source comprises a mini light emitting diode or a micro light emitting diode.

* * * * *